Semi-Annual Report for January-June, 1999
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Abstract

The algorithm development and validation activities of the first half of 1999 concentrated on field sampling in a variety of environments from a freshwater lake, to Case 1 oligotrophic, and to Case 2 coastal and estuarine waters using SeaWiFS, AVIRIS, AVIRIS LA, and PHILLS data. Our ATBDs of MOD19, MOD20, and MOD21 were updated to version 5. Three peer-reviewed publications appeared in print. A number of presentations and symposium papers were presented.

Tasks Accomplished Since January 1, 1999

1. Field experiments

a. Ecology of Harmful Algal Blooms (ECOHAB) cruise- 3/1 to 3/5

Jennifer Patch and Joe Andrews collected remote-sensing reflectance and water samples for absorption during an ECOHAB Gulf of Mexico experiment. The data will be used to test and adapt the global chlorophyll and CDOM algorithms for presence of bottom-reflected radiance in SeaWiFS and MODIS data.

b. Lake Okeechobee - 3/5 to 3/5

Robert Steward collected remote-sensing reflectance and water samples for absorption during Lake Okeechbee experiment. The data will be used to test and adapt the global chlorophyll and CDOM algorithms for turbid waters.

c. Tongue of the Ocean 2 – 4/13 to 4/20

Robert Steward and Jennifer Patch collected remote sensing reflectance and water samples for absorption during a TOTO2 experiment. The data were submitted to Simbios project and were used to calibrate SeaWiFS data to evaluate effects of stray light from the adjacent shallow banks on data and algorithms.

d. Calibration – 5/5 to 5/12

Robert Steward and Chris Cattrall participated in a calibration experiment on Mt. Lemon, Arizona. Four Spectrix spectral radiometers were radiometrically calibrated on the 40" integrating sphere at the University of Arizona's Remote Sensing Group (RSG). The Spectralon reflectance panels owned by USF were resurfaced according to manufacture instructions. The directional reflectance factor of each was measured at 5 degree increments from 10^o to 85^o and at 9 wavelengths from 443 to 1043 nm. The reflectance factors were measured and directly compared to a NIST standard and a RSG standard made from Algoflon. The Spectrix were transported to the top of nearby Mt. Lemon (~3000m) where direct-diffuse solar-based calibrations were conducted and compared with those derived from the sphere.

e. COBOP99 - 5/17 to 6/8

In conjunction with Navy-sponsored COBOP Project, a two-week exercise was conducted on the Lee Stocking Island of the Bahamas. A state-of-the-art data set was collected of inherent and apparent optical properties by investigators from various institutions. Dan Otis collected reflectance and water samples for absorption for USF. The PHILLS was flown on several transects over the area with vicarious calibration measurements conducted by USF from the R/V Suncoaster. Aerosol optical thickness (AOT) at 10 channels was measured with an automated solar radiometer along with downwelling irradiance and meteorological parameters.

USF also supported the experiment with several daily sampling trips on the RV Subchaser including remote-sensing reflectance, diffuse attenuation profiles, bottom albedo, depth, and bottom imagery. The USF slow-drop package was deployed. Remote sensing reflectance and water samples were collected for absorption measurements. Several methods to characterize the PHILLS sensor were employed. These data will be used to modify MODIS algorithms for use in shallow waters.

f. Ecology of Harmful Algal Blooms (ECOHAB) cruise- 7/5 to 7/8

Jennifer Patch collected remote-sensing reflectance and water samples for absorption during an ECOHAB Gulf of Mexico experiment. The data will be used to test and adapt the global chlorophyll and CDOM algorithms.

2. Peer-reviewed Publications

- Semi-Analytic MODIS Algorithms for Chlorophyll *a* and Absorption with Bio-Optical Domains Based on Nitrate-Depletion Temperatures by K. L. Carder, F. R. Chen, Z. P. Lee, S. Hawes, and D. Kamykowski, JGR, vol. 104, no. c3, pp 5403-5421, 1999.

  This paper describes Moderate Resolution Imaging Spectroradiometer (MODIS) algorithms for chlorophyll *a* concentration and phytoplankton and gelbstoff absorption coefficients. The algorithms are based on a semi-analytical, bio-optical model of remote-sensing reflectance, $R_{rs}(\lambda)$, where $R_{rs}(\lambda)$ is defined as the water-leaving radiance, $L_w(\lambda)$, divided by the downwelling irradiance just above the sea surface, $E_d(\lambda, 0^+)$. The $R_{rs}(\lambda)$ model has two free parameters, the absorption coefficient due to phytoplankton at 675 nm, a (675), and the absorption coefficient due to gelbstoff at 400 nm, $a_g(400)$. The R_{rs} model has several other parameters which are fixed, or can be specified based on the region and season of the MODIS scene. R_{rs} will be modeled using these parameters at each of the visible MODIS wavelengths, λ_i. The MODIS data-processing system will provide the water-leaving radiance, $L_w(\lambda_i)$, and $E_d(\lambda)$ values after atmospheric correction, and $R_{rs}(\lambda_i)$ values will be calculated. These $R_{rs}(\lambda_i)$ values will be placed into the model, the model is inverted, and a (675) and $a_g(400)$ are computed. Chlorophyll *a* concentration will then be derived simply from the a(675) value. For waters with high chlorophyll *a* concentrations where $R_{rs}(412)$ and $R_{rs}(443)$ are very low and the algorithm is insensitive, an empirical algorithm with $R_{rs}(488)$ and $R_{rs}(551)$ is used to estimate chlorophyll *a*. The algorithm also outputs both the total absorption coefficients, $a(\lambda_i)$, and the phytoplankton absorption coefficients, a (λ_i), at the visible MODIS wavelengths. Since absorption per unit chlorophyll varies by a factor of five or more for the global ocean due to variations in the pigment-to-chlorophyll ratios and pigment packaging or self-shading. The MODIS algorithms are parameterized for three different bio-optical domains: 1) unpackaged; 2) transitional; and 3) packaged. These provide a variation in domain type from high-light, warm conditions to lower-light, cool conditions and can be identified from space by comparing sea-surface temperature to nitrogen-depletion temperatures (NDTs) for each domain. Algorithm errors of more than 45% are reduced to errors of less than 30% with this approach, with the greatest effect occurring at the eastern and polar boundaries of the basins.

- Hyperspectral Remote Sensing for Shallow Waters: 2. Deriving Bottom Depths and Water Properties by Optimization by Zhongping Lee, Kendall L. Carder, Curtis D. Mobley, Robert G. Steward, and Jennifer S. Patch, Applied Optics, vol. 38, no. 18, pp3831-3843, 1999.

In earlier studies of passive remote sensing of shallow-water bathymetry, bottom depths were usually derived by empirical regression. This approach provides rapid data processing, but it requires knowledge of a few true depths to determine the regression parameters, and it can not reveal the in-water constituents. In this study, a newly developed hyperspectral, remote-sensing reflectance model for shallow water is applied to data from computer simulations and field measurements. In the process, remote-sensing reflectance spectrum is modeled by a set of values of absorption, backscattering, and bottom albedo and bottom depth, then it is compared with the spectrum from measurements. The difference between the two spectral curves is minimized by adjusting the model values in a predictor-corrector scheme. No information in addition to the measured reflectance is required. When the difference reaches a minimum, or the set of variables are optimized, absorption coefficients and bottom depths along with other properties are derived simultaneously. For computer-simulated data at a wind speed of 5m/s, the retrieval error was 5.3% for depths ranging from 2.0 to 20.0 meters, and 7.0% for total absorption coefficients at 440nm ranging from 0.04 to 0.24 m^{-1}. At a wind speed of 10 m/s, the errors were 5.1% for depth and 6.3% for total absorption at 440nm, respectively. For field data with depths ranging from 0.8 to 25.0 meters, the difference was 10.9% (R^2 = 0.96, N = 37) between inversion-derived and field-measured depth values and just 8.1% (N = 33) for depths greater than 2.0 meters. These results suggest that the model and method used in this study, which do not require in-situ calibration measurements, perform very well in retrieving in-water optical properties and bottom depths from above-surface hyperspectral measurements. This model provides the basis for understanding the effects of bottom radiance on water-leaving radiance spectra and will be simplified to permit MODIS applications in shallow waters.

- Determining optical absorption of colored dissolved organic matter in seawater with a liquid capillary waveguide by E.J. D'Sa, R.G. Steward, A.Vodacek, N.V. Blough, D.Phinney, Limnology and Oceanography 44(4), 1999, 1142-1148

  Optical absorption spectra of 0.2- mm filtered seawater samples originating from diverse oceanic and coastal waters were measured with a long pathlength capillary waveguide; results were compared with those of three different laboratory spectrophotometers. The 0.5-m-long 550- mm (inside diameter) aqueous waveguide uses only 120 ml of filtered seawater, making it convenient for use in flow-through cells or when sample volumes are restricted. Source light propagates inside the capillary waveguide by total internal reflection because of the lower refractive index of the waveguide walls with respect to the aqueous core. The absorption coefficient of colored dissolved organic matter (CDOM) at 355 nm and *S*, the slope of the log-linearized CDOM absorption spectra, were determined for all samples. The CDOM absorption spectra measured by the capillary waveguide closely matched that measured by spectrophotometers for CDOM concentrations varying over an order of magnitude. The deviations between the absorption spectra obtained with the capillary waveguide and those obtained with the standard spectrophotometers in-creased with decreasing total absorption and with increase in wavelength, presumably because of the greater baseline offsets observed in the capillary waveguide. The offsets are due to differences in refractive indices between the seawater samples and the freshwater reference. With a suitable reference, the capillary waveguide will be very useful for monitoring surface seawater CDOM absorption semicontinuously.

- Remote salinity and ocean color monitoring: aspects and performance in a coastal environment by E.J. D'Sa, J.B. Zaitzeff, and R.G. Steward, International Conference on Satellite Oceanography and Society. ed. D. Halpern (in press)

- Rapid remote assessments of salinity contrasts in Florida Bay and bio-optical variability by J.B Zaitzeff, E.J. D'Sa, C.S. Yentsch, J.L. Miller, R.G. Steward, and R. Ives in Linkages Between Ecosystems in the South Florida Hydroscape: The River of Grass Continues. eds. J.W. Porter and K.G. Porter (in press)

3. Presentations & Symposiums

- Recalibration and Atmospheric Correction to the AVIRIS Low Altitude data for a Tampa Bay Transit Using Lowtran 7 by F. Robert Chen, Kendall L. Carder, and Z.P. Lee was presented at the 22nd Atmosphere transmission meeting in Hanscom AFB.

  AVIRIS LA (Airborne Visible-Infrared Imaging Spectrometer, Low Altitude) has 10 nm spectral resolution from 400 nm to 2400 nm with a 4 m spatial resolution. AVIRIS LA data were collected from a Twin-Otter aircraft flying at 12,500 feet altitude over Tampa Bay, Florida on October 18, 1998 at 12 A.M. The AVIRIS LA preflight radiance calibration was adjusted vicariously using the method of Carder et al. (1993). The measured remote sensing reflectance spectra of Tampa Bay water taken at the time of the overflight using a field spectrometer was diffusely transmitted to 12,500 ft. and added to the path radiance calculated using Lowtran 7 with a winter marine aerosol type. The calculated and measured radiances at the aircraft matched closely for wavelengths longer than 470 nm, and a calibration adjustment was made for shorter wavelengths. Atmospheric radiance was then stripped from the entire scene.

4. Science Meetings

MODIS Sience Team, May 3-6, 1999.
SeaWiFS Science Team, May 18-20,1999.